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in its present form, and it is to be hoped that immediate and radical revision may make of it an acceptable and trustworthy guide to the literature of this interesting field.—JOSEPH S. CALDWELL.

NOTES FOR STUDENTS

Experimental embryology.—Morphologists and experimental workers have been aware for some time of a need of greater cooperation between their respective lines of research. Too often morphological or cytological studies are pursued without reference to important physiological conditions, while conclusions are drawn from experimental work which would not be warranted by morphology and cytology. It is becoming increasingly evident that results can be more properly interpreted in the additional light afforded by supplementary researches in a related field. The value of this cooperative method is emphasized in a recent paper by KUSANO⁴ on angiosperm embryology. A favorable form for such study was found in the orchid *Gastrodia elata*. Since the inflorescence develops at the expense of material stored in a tuber, it is a simple matter to maintain the plant under normal nutritive conditions. Some of the results of KUSANO's research, which is still in progress, are cited below.

The normal development in *Gastrodia* is as follows: A subepidermal archesporial cell becomes the megaspore mother cell and undergoes the two maturation divisions. In some cases reduction, which is said to consist in a simple pairing and separation of the chromosomes on the equator of the spindle, fails to occur, so that the functioning megaspore and gametophyte are sometimes haploid and sometimes diploid. The embryo sac contains only 4 nuclei, 3 of which are organized as an egg apparatus. This reduced condition is regarded as an economical specialization correlated with the peculiar vegetative habit. Many irregularities which occur are related to poor nutrition. At fertilization, which occurs only in haploid sacs, one of the male nuclei fuses with the egg nucleus, while the other fuses with the single polar and a synergid nucleus. The fertilized egg forms the usual undifferentiated proembryo, which is nourished through the suspensor and large nucellar cells. The endosperm nucleus does not divide. The following time schedule was determined: two days before the flower opens the ovule is yet in a rudimentary stage; the embryo sac is completed 3 days after bloom; fertilization occurs the 4th day after pollination; the fertilized egg divides the 5th day; the seed is completed the 14th or 15th day; the capsule dehisces about the 23d day. This exceptionally rapid development (for Orchidaceae) is correlated with the fact that it occurs at the expense of stored food. Occasionally two archesporial cells arise in a single ovule and undergo complete development.

An extended series of experiments led to the following conclusions: After a few days the fertilizing power of the pollen is lost and the ovules become

⁴ KUSANO, S., Experimental studies on the embryonal development in an angiosperm. Jour. Coll. Agric. Tokyo 6:7-120. pls. 5-9. figs. 28. 1915.

incapable of fertilization. Although the development of ovules and embryo sacs is promoted by the presence of pollen tubes, they are completed in unpollinated flowers unless nutritive conditions are too severe. In such flowers the egg apparatus may remain in healthy condition 8 or 9 days. In some cases it then degenerates; in other cases the ovule forms an embryoless seed, the number of these seeds in the fruit depending upon nutrition. Such embryoless seeds may develop from ovules with either the haploid or the diploid egg.

If the floral axis is separated from the tuber, scarcity of food material causes an imperfect development of ovarial and ovular tissue in pollinated flowers, but it does not interfere with the number of ovules going into seed formation nor with the development of the embryo. If pollinated flowers are cut from the floral axis and kept moist, fertilization occurs but the ovary does not grow. Some of the ovules develop into seeds with imperfect coats, while others degenerate after one or two embryonal divisions have occurred. The effects of reduced nutrition are here manifest. Of all the parts the embryo is the least liable to be retarded in development by poor nutritive conditions. It is evident that the embryo can develop without the accompanying development of the ovule or ovary tissue, and that the seed coat may likewise form without the development of the embryo or ovary wall. The growth of the latter, however, seems to be dependent upon the development of the ovules.

Self-pollination appears to be as effective as cross-pollination in *Gastrodia*. The pollinium will germinate within the cavity of the ovary and effect fertilization. Pollination with foreign (*Bletia*) pollen resulted in fruits and seeds of normal form and size, but the seeds were without embryos; no fertilization occurred. If both *Gastrodia* and *Bletia* pollen are placed on the same stigma the fertilizing activity of the *Gastrodia* pollen is greatly hindered.

With regard to parthenocarpy, the author recalls the distinction between vegetative (WINKLER) or autonomic (FITTING) parthenocarpy, in which embryoless fruits are formed without the agency of any external factor, and stimulative (WINKLER) or aitionomic (FITTING) parthenocarpy, in which the formation of embryoless fruit is induced by pollen or some other agent. Both types occur in *Gastrodia*; the aitionomic fruits are of normal size, while the autonomic ones are much smaller. The former appear to be well developed because the pollen or other agent stimulates nutritive activity; it seems that the size of the fruit may depend upon the intensity of the stimulus and also upon its duration. Parthenocarpic development of the ovary is dependent upon ovular development, the amount of seed apparently governing the size of the capsule.

Polyembryony occurs frequently in *Gastrodia*, and is correlated with delayed pollination. One embryo arises from the fertilized egg, and the other probably from a fertilized synergid.

Although diploid eggs occur frequently in *Gastrodia* their apogamous development was not observed in any case. It is interesting to note, however, that KUSANO saw several cases in which the nucleus of a haploid egg under-

went division. This is the first step in true parthenogenesis, but it is never accompanied by cell division and never leads to embryo formation. Other works on apogamy are cited, but the author believes the cytological facts regarding such matters are yet too few to warrant the formulation of a hypothesis on the evolution of parthenogenesis from amphimixis.

The value of contributions of this sort is obvious. The correlation of physiological conditions and morphological phenomena is clearly shown. This should lessen the morphologist's frequent neglect of physiology, and, on the other hand, should lead to a more careful checking up of experimental results, especially those in plant breeding, by morphological study.—L. W. SHARP.

Chromosomes and Mendelian inheritance.—STURTEVANT⁵ presents a recapitulation with much new data bearing upon the "coupling" and "repulsion" of Mendelian genes in the fruit fly (*Drosophila ampelophila*), and ably discusses the bearing of these breeding results upon the chromosome interpretation of Mendelian phenomena. The large number of "cross-overs" (that is, changes from coupling to repulsion and vice versa between two given genes) and the relatively small number of chromosomes in the fruit fly, makes this organism very favorable material for such a study. Over 40 Mendelian characters of the fruit fly have been studied by MORGAN and his students, and these characters form four groups, so related to one another that all of the characters within one of these groups show "linkage" with one another; while those which have been sufficiently studied are independent of genes included in any one of the other groups. Each of these groups of characters is believed to be carried by a single pair of homologous chromosomes. On the basis of the relative number of cross-overs between different genes, considered two by two, the number of cross-overs which may be expected in any untried combination among the same series of "linked" genes may be readily calculated. Each gene is assumed to occupy a definite position or "locus" in the chromosome, and these loci are represented as forming a linear series whose distances from one another is measured by the relative frequency of cross-over. When cross-overs between two genes are rare, the two loci involved are assumed to be very near each other, and when cross-overs are frequent it is assumed that the two loci in question are correspondingly removed, though still lying in the same chromosome. No less than six of these loci have been established in a single chromosome, by a fairly adequate amount of data, and the correspondence between calculated distances and the observed numbers of cross-overs is convincing as to the fundamental value of this method of representation. Furthermore, the discrepancies between the observed and calculated results are so consistently in the same direction that they make possible another important

⁵ STURTEVANT, A. H., The behavior of the chromosomes as studied through linkage. *Zeitschr. Ind. Abstamm. Vererb.* 13:234-266. 1915.